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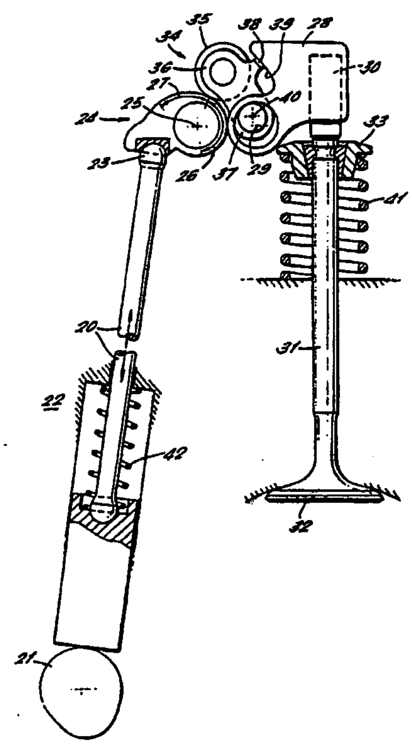
(57) Abstract

The present invention provides in a first aspect, with reference to the Figure, a valve operating mechanism for operating an inlet and/or exhaust valve (32) of an internal combustion engine. The mechanism comprises oscillating cam means (24) mounted for rotation about a first fixed axis (25). Means (20, 21) for oscillating the oscillating cam means (24) is provided which oscillates the oscillating cam means (24) between first and second rotational positions. Rocker means (28) is mounted for rotation about a second axis (29) and the rocker means engages and drives a valve (32). Cam follower means (34) is connected to the rocker means (28) and also engages the oscillating cam means (24). Thus, the rocker means (28) is rocked by the oscillating cam means (24) to drive the valve (32); the cam follower means following the profile of the oscillating cam means (24) between first and second contact positions respectively at the first and second rotational positions of the oscillating cam means (24). The cam follower means (34) is moveable with respect to the rocker means (28) and control means is provided for adjusting the position of the cam folllower means (34) relative to the axis of rotation of the rocker means (28) whereby the location of the first and second contact positions on the oscillating cam means (24) can be varied. The present invention provides in a second aspect, again with reference to the Figure, an engine having a camshaft (21) driven to rotate in timed relationship to the crankshaft of the engine and a reciprocating push rod (20) driven by the camshaft (21) which is used to transmit motion to the cylinder head of the engine. The engine is provided with transmission means to transmit motion from the push rod (20) to an inlet or exhaust valve (32) of the engine whereby the valve (32) is driven to reciprocate. The transmission means comprises oscillating cam means (24) directly or indirectly driven by the push rod (20), cam follower means (34), which follows the profile of oscillating cam means (24) and which is in driving connection with the inlet or exhaust valve (32) and means to alter the position of the cam follower means (34) relative to the oscillating cam means (24) which allows the cam follower means (34) to be controlled to follow different surface sections of the oscillating cam means (24) such that valve motion can be varied.



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VALVE OPERATING MECHANISM FOR INTERNAL COMBUSTION ENGINES

The invention relates to a valve operating mechanism suitable for internal combustion engines and in particular to a mechanism which is operable to vary valve lift and timing in different engine operating conditions.

A typical internal combustion engine currently available uses a camshaft in direct or indirect engagement with the inlet and exhaust valves of the engine which controls the opening and closing of the inlet and exhaust valves and the lift of the valves. The camshaft is rotated at a speed proportional to the speed of rotation of the engine and the timing of the opening and closing of the inlet and exhaust valves in terms of degrees of crankshaft rotation after top dead centre (ATDC) in each engine cycle is constant for all engine operating conditions. The cam profile of the camshaft must be chosen to provide a compromise between the cam profile for efficient operation at high engine speeds and the cam profile necessary for efficient operation at low engine speeds.

Several systems have been proposed in the past which provide solutions to the problems of ordinary camshaft driven valve operating mechanisms. For instance in PCT/GB91/00232 and PCT/GB91/00233 mechanisms are shown which allow a first cam profile to be used at low engine speed/loads and a second cam profile to be used by the engine at high engine speed/loads. Whilst the systems provide advantages over the traditional cam operated valve mechanisms they can only provide for discrete definite changes in cam profile and do not allow smooth changes in valve lift and valve timing with engine speed and/or load.

In the U.K. application GB 2047801 there is

proposed a valve operating system for an overhead camshaft engine which allows variable valve lift and valve timing. In the system a camshaft with a first cam is rotated in timed relationship to the rotation of the engine. A second cam is engaged with the inlet or exhaust valve of the engine. A rocker arm is interposed between the first and second cams, the rotating first cam causing rocking of the rocker arm and thereby causing the second cam to rotate in an oscillatory fashion about its pivot axis. The rocker arm is mounted eccentrically on a rocker shaft and the rocker shaft is adjustable to shift the axis of rocking movement of the rocker arm relative to the axes of the first and second cams. In this way variation of valve lift can be achieved. The variation of valve lift and timing is achieved since with the rocker arm in different positions the valve is actuated by different portions of the surface of the second cam. Since the second cam varies in profile along its cam surface, driving of a valve by contact with different portions of the surface will give different driving motion of the valve.

The apparatus of the GB 2047801 document is arranged such that there is no discrete change in the valve operation and instead the alteration of valve operation occurs gradually with rotation of the rocker shaft about its eccentric mounting.

The arrangement of the GB 2047801 system is disadvantageous in certain respects.

There is generally very little room at a cylinder head to install valve operating mechanisms. The valve operating mechanism should be of compact packaging size to allow it to be positioned alongside inlet and exhaust passages, or cooling passages etc. The arrangement of GB 2047810 requires a considerable amount of space, with the axes of the first and second cams being widely spaced from each other.

The present invention provides a valve operating mechanism for operating an inlet and/or exhaust valve of an internal combustion engine comprising

oscillating cam means mounted for rotation about a first fixed axis,

means for oscillating the oscillating cam means between first and second rotational positions,

rocker means mounted for rotation about a second axis in driving engagement with a valve,

cam follower means connected to the rocker means and in engagement with the oscillating cam means whereby the rocker means is rocked by the oscillating cam means to drive the valve, the cam follower means following the profile of the oscillating cam means between first and second contact positions respectively at the first and second rotational positions of the oscillating cam means,

characterised in that the cam follower means is moveable with respect to the rocker means and control means is provided for adjusting the position of the cam follower means relative to the axis of rotation of the rocker means whereby the location of the said first and second contact positions on the oscillating cam means can be varied.

Preferably the rocker means is rockable about a fixed axis.

A disadvantage the GB 2047801 system arises since the configuration of the apparatus necessitates the provision of three surfaces with sliding friction. The avoidance of friction in any valve operation mechanism is very important since a valve operating mechanism will operate at high frequencies of motion and therefore considerable friction will be generated between sliding surfaces and there will be considerable wear between sliding surfaces. The wear of sliding surfaces is a significant problem in valve operating mechanisms since wear can cause unwanted alteration in valve motion.

Preferably the cam follower means comprises a roller in contact with the oscillating cam means mounted for rotation on a link member connected to the rocker means, which link member is moveable by the control means to move the roller relative to the rocker means. Preferably the rocker means is mounted on a shaft and is rotatable relative thereto, the link member is eccentrically mounted on the shaft, and the control means comprises means to rotate the shaft whereby the link member and the roller are moved relative to the rocker means.

Preferably a hydraulic lash adjuster is provided in the rocker means, which hydraulic adjuster has a surface which abuts the top of the valve stem of the inlet or exhaust valve.

The present invention also provides an engine having an inlet or exhaust valve with an associated valve seat, operated by a valve operating mechanism as previously discussed wherein the inlet or exhaust valve is biased into the associated valve seat by a valve spring and the biasing force of the valve spring is used to maintain contact between the cam follower means and the oscillating cam means when the valve is lifted from the associated valve seat.

A first preferred embodiment of an engine according to the invention has a rotating overhead camshaft for driving the valve wherein the means for oscillating the oscillating cam means comprises cam follower means connected to the oscillating cam means which engage the overhead camshaft and follow the cam profile thereof.

A second preferred embodiment of an engine according to the invention has a camshaft mounted in the lower half of the engine with a reciprocating push rod driven thereby which transmits motion to the cylinder head, wherein the means for oscillating the oscillating

cam means comprises connection means for connecting the oscillating cam means to the reciprocating push rod.

Preferably second cam follower means comprising roller means is provided for the engine, the roller means engaging a cam of the camshaft of the engine and following the profile thereof. The roller means will engage the overhead camshaft of an overhead camshaft engine or will be connected to the push rod of a push rod engine. The roller means reduce frictional losses.

In a further aspect the present invention provides an engine having a camshaft driven to rotate in timed relationship to the crankshaft of the engine and a reciprocating push rod driven by the camshaft which is used to transmit motion to the cylinder head of the engine, wherein transmission means is provided to transmit motion from the push rod to an inlet or exhaust valve of the engine whereby the valve is driven to reciprocate characterised in that the transmission means comprises

oscillating cam means directly or indirectly driven by the push rod,

cam follower means which follow the profile of the oscillating cam means and which is in driving connection with the inlet or exhaust valve and

means to alter the position of the cam follower means relative to the oscillating cam means which allows the cam follower means to be controlled to follow different surface sections of the oscillating cam means such that the valve motion can be varied.

GB 2047301 provides a system of valve operation which is suitable for an engine having overhead cam shafts. However, the system provided by the document is not suitable for use in a push rod engine and therefore the problem of providing a valve operating mechanism which allows variable valve timing and valve lift remains outstanding for the push rod engine.

Preferred embodiments of the present invention will now be described with reference to the accompanying drawings in which:-

Figure 1 is a schematic diagram illustrating the operating principle of the invention,

Figure 2 is a graph of valve lift against crankshaft degrees in an engine cycle for various operating conditions of a valve operating mechanism of the invention,

Figure 3 is a schematic representation of a first embodiment of valve operating mechanism according to the invention, suitable for use in a push rod engine,

Figure 4A, 4B, 5A, 5B and 6A, 6B all illustrate the operating principle of preferred embodiments of valve operating mechanisms according to the invention.

Figure 7 is a schematic representation of a second embodiment of valve operating mechanism according to the invention suitable for use in an overhead camshaft engine.

Referring first to Figure 1, the figure illustrates the operating principle of the invention. At 10 means is provided for causing oscillating motion (indicated by the arrows). The oscillating motion is transmitted by the link 11 to an arm 12 which is of adjustable length (indicated by the split shown in the middle of the arm in the diagram). The arm 12 has a flat surface 14 and a ramped surface 15 which serve as the cam means of the arrangement.

In Figure 1 there can be seen a valve 16 which is the inlet or exhaust valve of an internal combustion engine. The valve 16 has a stem 17 which is in contact with the adjustable length arm 12. A spring 18 maintains contact between the valve stem 17 and the adjustable length arm 12.

The arm 12 is always oscillated through the same distance D1. However, since the length of the arm 12 is

adjustable, the motion of the valve 16 can be varied. Taking the Figure 1 to represent the extreme left position of the adjustable length arm 12, the oscillating motion imposed on the arm 12 will cause the adjustable length arm 12 to move to the right as shown in the drawings and the arm will move relative to the valve stem 17 such that the valve stem 17 moves along the flat portion 14 of the cam surface of the arm 12 and at the extreme right position of the arm 12 just remains in contact with the flat portion 14, giving no lift of the valve 16. This condition would be the minimum valve lift operating condition and this is shown as the line 90 in the graph of Figure 2.

By adjusting the length of the arm 12 the arm is moved relative to the valve stem 17. By increasing the length of the arm 12 the arm moves to the right with respect to the valve stem 17 and therefore for the same distance of oscillatory motion D1 the top of the valve stem 17 moves along a different portion of the cam profile surface of the arm 12. Motion of the valve stem 17 along the ramp 15 causes downward motion and therefore valve lift. With increasing length of the arm 12 the valve stem 17 will move further along the ramp portion 15 of the cam profile surface with correspondingly greater valve lift and longer valve opening duration.

The length of the arm would be adjusted with changes in engine speed and/or load to achieve the lifting duration desirable for particular engine operations. The valve lift lines 90, 100, 110, 120, 130 and 140 of Figure 2 show different valve lift and duration for different engine operating conditions. The line 90 would correspond to valve deactivation and the line 140 would correspond to the maximum lift and duration possible, which would be used at high engine speeds or loads.

A first embodiment of the invention is shown in Figure 3 of the application, which embodiment is suitable for use with a push rod engine. The drawing shows the push rod 20 which is driven by a camshaft 21 to reciprocate in a bore in the cylinder block of the engine 22. The push rod 20 is connected at its upper end by a pivot joint 23 to cam means 24. The cam means 24 comprises a member rotatable about a fixed pivot axis 25. The cam means 24 has a cam profile along its outer surface. The cam profile includes a first portion 26 of constant radius and a second portion 27 of increasing radius.

A rocker 28 is rockable about a fixed pivot axis 29. A hydraulic lash adjuster 30 is located in the rocker 28 and contacts the top of a valve stem 31 of a cylinder head valve 32 of an engine. A valve spring 41 acts between the cylinder head and a collar 33 attached to the valve stem 31 to bias the valve 32 into its valve seat.

The rocker 28 is provided with cam follower means 34 which follows the surface of the cam means 24. The cam follower means 34 comprises a cam follower roller 35 rotatably mounted on a link member 36. The link member 36 is connected at its lower end to a shaft (not shown in the drawing for reasons of clarity) which extends through aperture 37. The rocker arm 28 is rotatable with respect to the shaft about the axis 29 which is the principal axis of the shaft. The link 36 is rotatably connected to the shaft for rotation about an axis 40 which is offset from the axis 29.

The link member 36 has abutment means 38 for abutting the reaction surface 39 provided on the rocker arm 28.

The shaft can be rotated to rotate the axis 40 of the rotatable mounting of link 36 about the fixed axis 29 of the rocker arm 28 such that the distance between

the axis 29 and the point of contact between the roller 35 and cam means 24 is varied.

The shaft is rotated relative to the rocker arm 28 by suitable motor means to effect adjustment. Since the pivot point 40 of the link 36 is attached to the shaft, rotation of the shaft relative to the rocker arm 28 causes movement of the pivot point 40 relative to pivot point 29 and corresponding movement of the link 36 relative to the rocker arm 28.

Considering now the operation of the arrangement shown in Figure 3 in use of the apparatus the camshaft 21 will be driven to rotate at the rotational speed proportional to the rotational speed of the crankshaft of the engine, being driven by suitable connection means. The cam surface on the camshaft 21 causes reciprocal motion of the push rod 20, which in turn causes the cam means 24 to oscillate about the pivot axis 25. As the cam means 24 rotates about its axis 25 the roller 35 of the cam follower means of the rocker arm 28 moves along the cam profile surfaces 26 and 27. The valve 32 remains on its seat whilst the roller 35 moves along the surface 26, because the surface 26 is of constant radius. However, when the roller starts to move along the surface 27 the rocker arm 28 is caused to rotate clockwise about the fixed pivot point 29 and to cause the valve 32 to move downwardly and open the associated port in the engine cylinder.

Eventually, the push rod 20 will move downwardly in the cylinder block, following the profile of the camshaft 21, under the influence of a spring 42 acting between the cylinder block 22 and the push rod 20. The push rod 20 will pull the cam means 24 in a counterclockwise direction on downward motion and the roller 35 will move from the cam profile section 27 to the section 26 of the cam profile surface, with the

valve 32 being allowed to return to its valve seat under the biasing action of the valve spring 41. The valve spring 41 exerts a biasing force to maintain contact between the roller 35 and cam means 24.

As shown in the Figure 3, the mechanism is in its position for maximum valve lift and maximum duration of valve lift. With the valve 32 in its position against the valve seat the cam follower roller is positioned just at the beginning of the cam profile lifting surface 27. Any motion of the cam means 24 in a clockwise direction will cause valve lift. Such an operating condition will be ideally suited for high engine speeds or loads when it is required to obtain a large degree of valve opening in each cycle since there is little time for flow of gases in each cycle due to the brevity of each cycle at high engine speed.

At lower engine speeds or loads less valve lift and a short valve opening period is required for efficient operating of the engine and this is achieved by rotating the control shaft of the apparatus such that the pivot point 40 is rotated relative to the fixed pivot point 29. The distance between the pivot point 29 of the rocker and the axis of rotation of roller 35 is thus varied, with the abutment means 38 moving along the reaction surface 39. Since the roller 35 is moved relative to the rocker arm 28 it will roll along a different portion of the cam profile surface of the cam means 24. A change in valve timing and valve lift will thus be occasioned.

The operation principle is illustrated in Figures 4A and 4B, 5A and 5B and 6A and 6B.

In Figure 4a the cam means 24 is in its idle position (i.e. when the push rod 20 is moving along the base circle portion of the cam 21).

Cam means 24 is then rotated through a set number of degrees by the push rod 20 to its position of maximum

clockwise rotation shown in Figure 4b. The rotational axis of roller 35 is at a distance Y1 from the rotational axis 29 of the rocker arm 28. Y1 is the maximum distance possible in the embodiment.

The roller 35 during the idle portion of the cam means 24 is in contact with a point X1 on the cam profile surface which is a distance R1 from the rotational axis 25 of the cam means. The distance R1 is chosen such that the valve means 32 is in contact with its valve seat.

Throughout the clockwise rotation of the cam means 24 the roller 35 moves along the cam profile surface with increasing radial distance from the rotated arms 25 until it reaches the maximum displacement at X2 (a distance of R2 from the axis of rotation 25). The process is then reversed for counter clockwise motion of the cam means 24.

Considering now Figures 5A and 5B the distance between the centre of rotation of the roller 35 and the axis of rotation 29 of the rocker arm 28 has been altered to Y2, where Y2 is less than Y1. Consequently, the roller 35 is positioned during the idle portion of the motion of the cam means 24 at a position X3 on the cam profile surface, which is at a radial distance R3 from the centre of rotation 25 of the cam means 24. The radial distance R3 is chosen to be a distance which allows contact of the valve 32 with its valve seat.

As the cam means 24 is rotated clockwise the roller 35 moves from position X3 through position X4 to position X5, the position at maximum clockwise rotation of the cam means. Whilst the roller 35 moves between positions X3 and X4 it is not displaced radially of the cam means 24, since the distance R4 at X4 is the same as the distance R3 at X3. Consequently, the valve 32 is maintained in its closed position.

When the roller 35 moves from X4 to X5 it moves

over a cam profile surface of increasing distance from the axis of rotation 25 (R5 being greater than R4). Consequently, the valve is lifted from its valve seat. However, comparing 5B with 4B it will be noticed that the radial distance R5 is less than R2 and the maximum valve lift occasioned with the mechanism operating as shown in 5A and 5B is less than the maximum valve lift achieved at 4B.

The mechanism is provided with the possibility of valve deactivation as shown in Figures 6A and 6B. With a distance Y3 chosen between the axis of rotation of roller 34 and the axis of rotation 29, the roller 34 moves from a position X6 on the cam profile surface to a position X7. Both distances R6 and R7 are the same and both are chosen such that the valve 32 remains against its valve seat. Consequently, the valve 32 remains inactive throughout rotation of the cam means 24.

The second embodiment of the invention illustrated in Figure 7 is suited to use in an overhead camshaft engine. The overhead camshaft of the engine is shown as 50 in the Figure. The operation of the overhead camshaft embodiment is substantially the same as the operation of the push rod embodiment already described and will not be further commented on. However, there are two significant differences between the mechanisms of the two embodiments.

The first difference is an alteration in the cam means. Cam means 24 present in the first embodiment has been replaced by cam means 51. The cam means 51 is rotatable about an axis 25 in identical fashion to the cam means 24 and the cam means 51 has cam profile surfaces 27 and 26 which are identical to those of the cam means 24. The difference between the cam means 51 and 24 is the provision of a cam follower surface 52 connected to the cam means 51 which follows directly the profile of the overhead camshaft 50 of the overhead

camshaft engine in which it is used.

The second difference between the embodiments of Figures 3 and 7 is the replacement of the spring 42 with a light spring 53. The light spring 53 keeps the cam follower surface 52 of the cam means 51 in engagement with the cam 50.

In both of the first and second embodiments of the invention (Figures 3 and 7) the control shaft (not shown) will be driven to rotate by an electric motor (not shown) controlled by a suitable electrical or electronic controller. Sensors will be provided to measure various engine parameters (eg. speed, load and temperature) and provide signals indicative of the measured parameters to the controller. The controller will typically be an electronic controller having a memory map of optimum operating instructions for various combinations of inputs. The controller will generate suitable control signals to control the electric motor.

In the above embodiments it will be noted that friction is kept to a minimum since sliding contact is required only between the cam shafts 21 and 50 of and cam follower members. The contact between the rocker arm 28 and the cam surfaces 26 and 27 is provided by a roller which is used to minimise frictional losses and to minimise wear. Rollers could also be included as cam follower means to engage the cam means 21 and 50 and this would further reduce frictional losses.

The valve operating mechanisms are compact in nature and facilitate the use of hydraulic lash adjustors.

It will also be seen that the invention provides a valve mechanism suitable for a push rod engine.

FIG. 3.

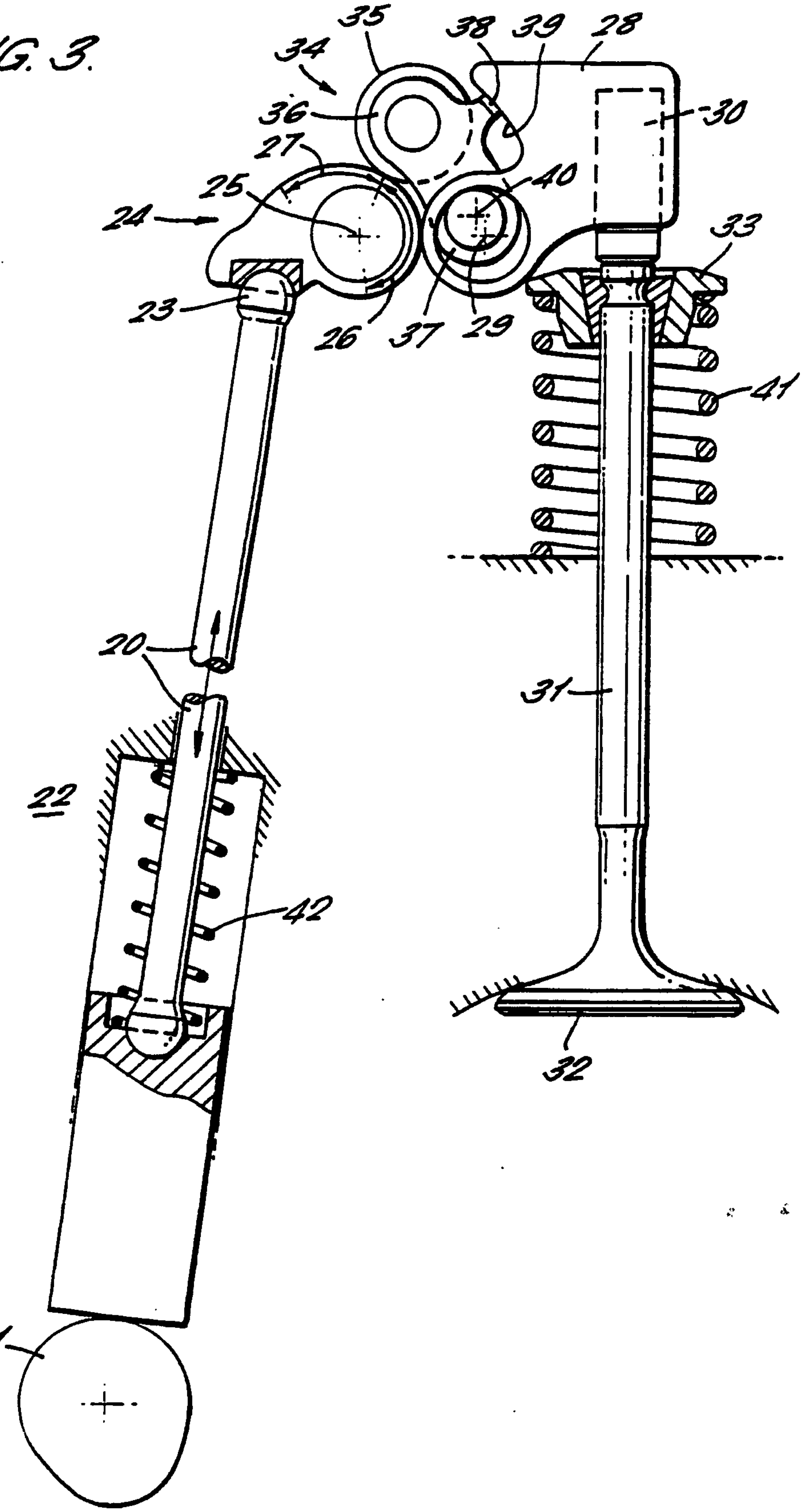

FIG. 4A.

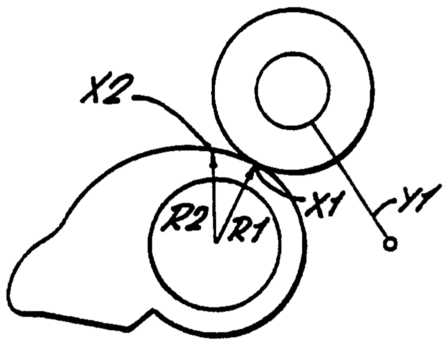

FIG. 4B.

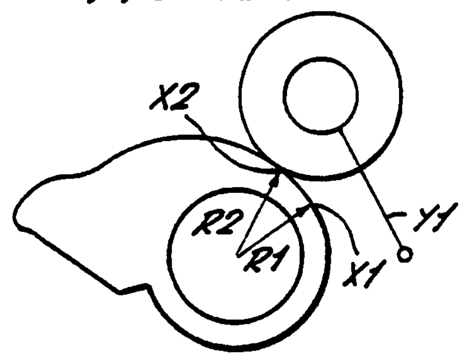

FIG. 5A.

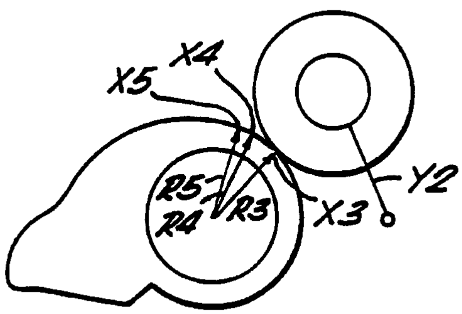

FIG. 5B.

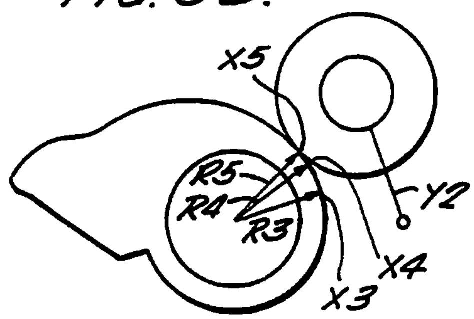

FIG. 6A.

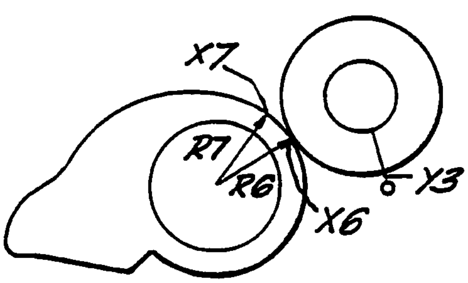

FIG. 6B.

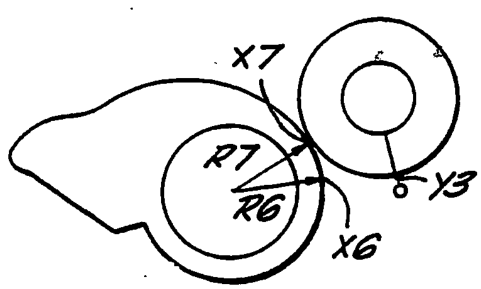

FIG. 7.